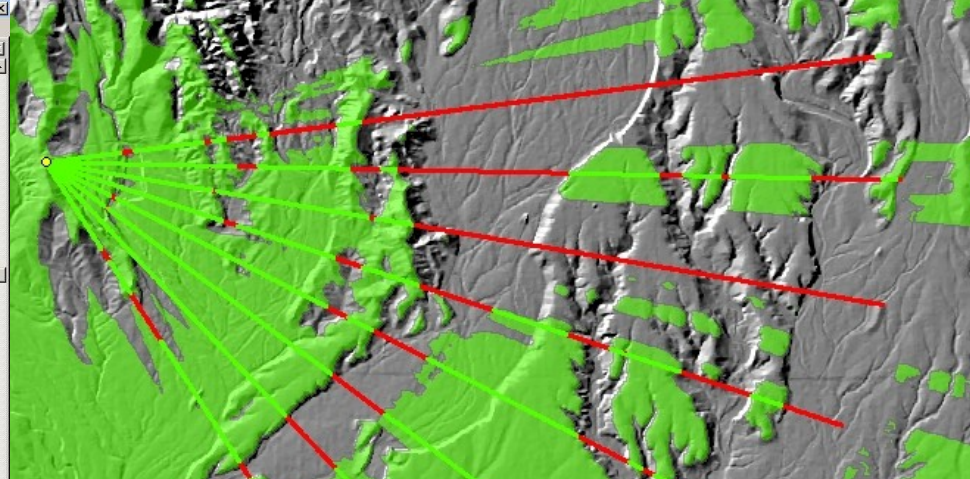
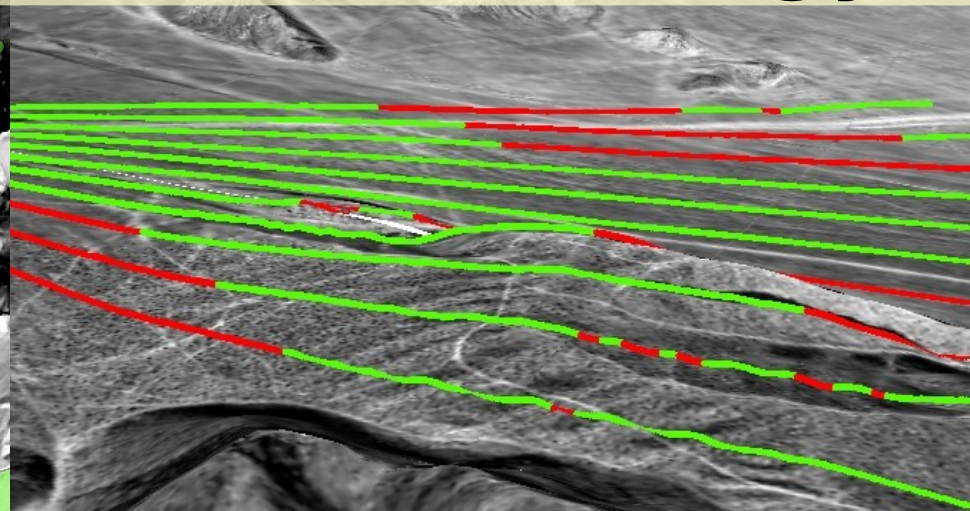
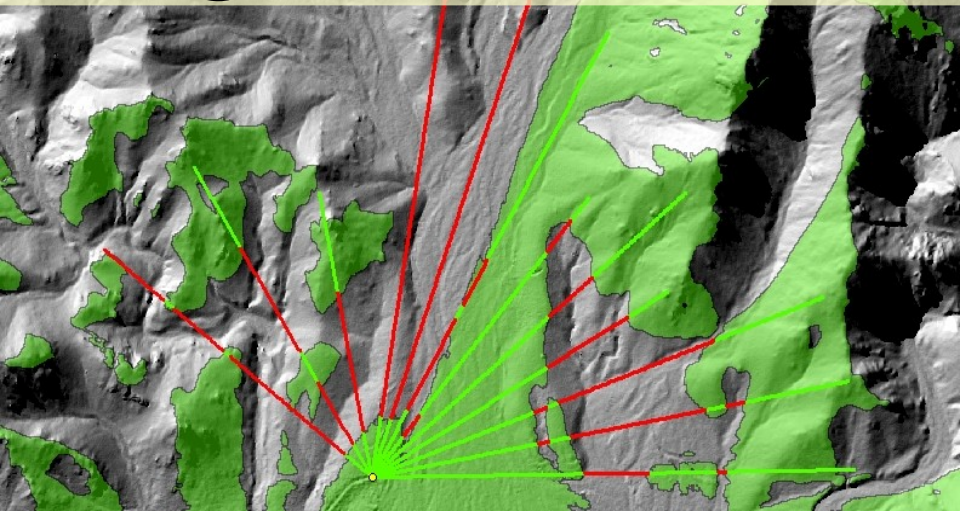




Line-of-Sight Field and Terrain Data Available from TEC and Overview of TEC Line-of-Sight Application and Algorithm Validation Methodology



Data Sets

Field Data and High Resolution DEM Coverage

- Field data in Access, Excel, or Text Formats
- High resolution (1 - 5 meter) photogrammetrically derived DEMs in Arc ASCII, ASCII, GeoTIFF, ERDAS .img formats, etc.
- **Fort Benning, GA**
- **Fort Hood, TX**
- **Irwin East, CA (National Training Center)**
- **Irwin West, CA (National Training Center)**
- **Twentynine Palms, CA**
- **Yakima, WA**

Field Data Characteristics

<u>Test Area</u>	<u>Collected Field Points</u>	<u># of Observer Positions</u>	<u># of Azimuths</u>	<u>Sampling Interval (meters)</u>	<u>Std. Deviation of Field Point Elevations (meters)*</u>	
Fort Benning A**		18342	6	41	0.9	7
Fort Benning B**		18342	6	41	0.9	7
Fort Hood	28412	7	51	3.5	7	
Irwin East	37077	5	35	3.5	36	
Irwin West	31483	4	35	3.5	53	
29 Palms	8163	3	29	3.5	28	
Yakima	34109	5	39	3.5	34	
Yuma	36843	5	61	5.0	22	

Observer heights range between 1.075 meters and 1.75 meters.

Target heights range between 1.0 meters and 3.067 meters.

*Terrain roughness (sigma-t) of the elevations of the field points is moderate (standard deviation of 18 - 61 meters) for all test areas except Fort Benning which is smooth (standard deviation of < 18 meters).

** The same field points at Fort Benning were recorded simultaneously at two different target heights (A = 1.0

Field Data in Access Database

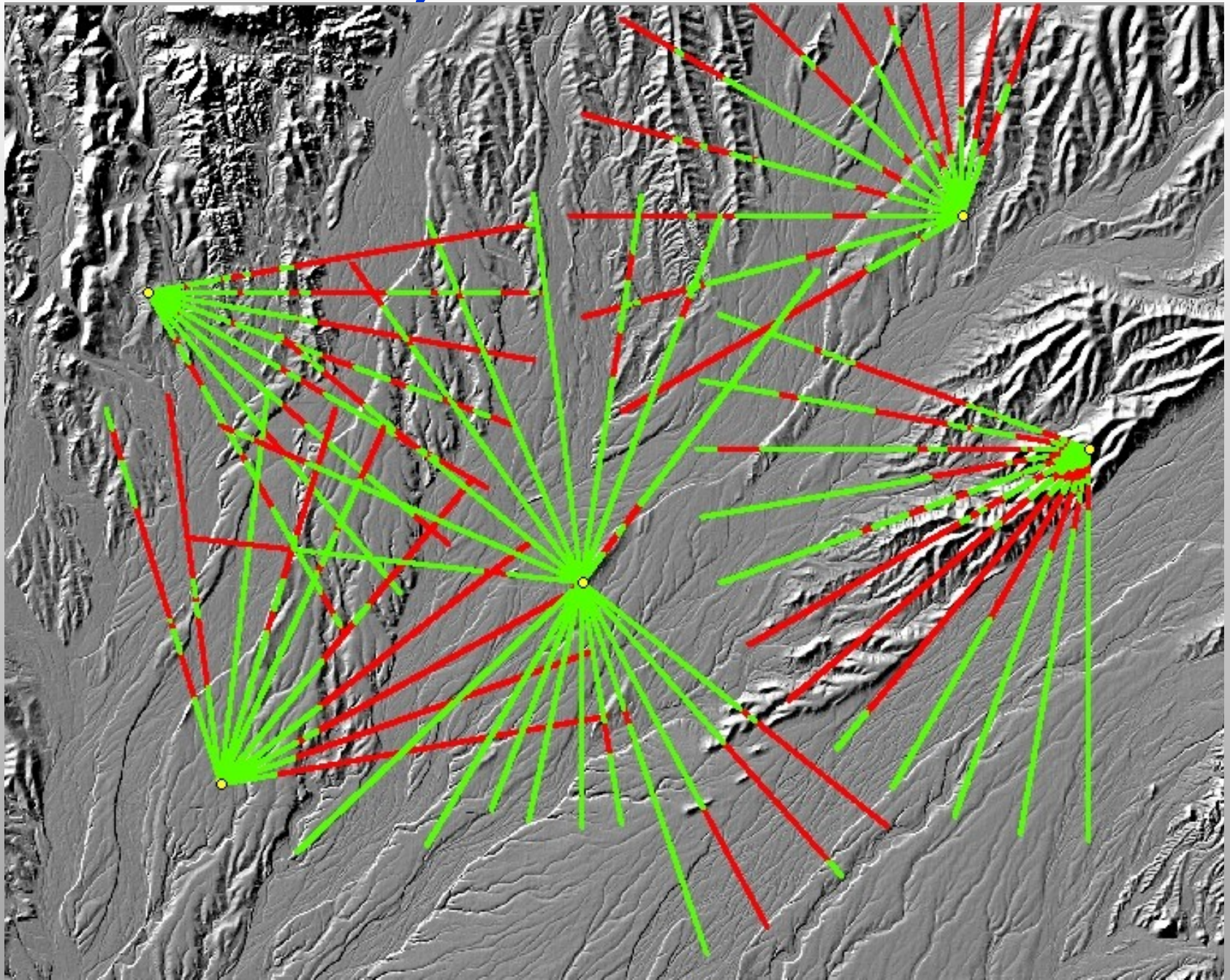
Microsoft Access - [YumaSite3 : Table]												
File Edit View Insert Format Records Tools Window Help												
Counter	SiteNum	AzimuthNum	SensorX	SensorY	SensorZ	TargetX	TargetY	TargetZ	SensorTargetDist	AzimuthCounter	FieldLOS	
1501	3	5	745278.8	3669481.8	1.618	745169.8	3669781	3.067	318.46	65	1	1
1502	3	5	745278.8	3669481.8	1.618	745168.1	3669785.8	3.067	323.5	66	1	1
1503	3	5	745278.8	3669481.8	1.618	745166.5	3669790.2	3.067	328.29	67	1	1
1504	3	5	745278.8	3669481.8	1.618	745164.8	3669794.8	3.067	333.09	68	1	1
1505	3	5	745278.8	3669481.8	1.618	745163.1	3669799.5	3.067	338.13	69	1	1
1506	3	5	745278.8	3669481.8	1.618	745161.4	3669804	3.067	342.94	70	1	1
1507	3	5	745278.8	3669481.8	1.618	745159.8	3669808.8	3.067	347.98	71	1	1
1508	3	5	745278.8	3669481.8	1.618	745158.1	3669813.2	3.067	352.76	72	1	1
1509	3	5	745278.8	3669481.8	1.618	745156.4	3669818	3.067	357.8	73	1	1
1510	3	5	745278.8	3669481.8	1.618	745154.8	3669822.5	3.067	362.61	74	1	1
1511	3	5	745278.8	3669481.8	1.618	745153.1	3669827	3.067	367.42	75	1	1
1512	3	5	745278.8	3669481.8	1.618	745151.4	3669831.8	3.067	372.46	76	1	1
1513	3	5	745278.8	3669481.8	1.618	745149.8	3669836.2	3.067	377.24	77	1	1
1514	3	5	745278.8	3669481.8	1.618	745148.1	3669841	3.067	382.28	78	0	0
1515	3	5	745278.8	3669481.8	1.618	745146.4	3669845.5	3.067	387.09	79	1	1
1516	3	5	745278.8	3669481.8	1.618	745144.7	3669850	3.067	391.89	80	1	1
1517	3	5	745278.8	3669481.8	1.618	745143	3669854.8	3.067	396.93	81	1	1
1518	3	5	745278.8	3669481.8	1.618	745141.3	3669859.2	3.067	401.74	82	0	0
1519	3	5	745278.8	3669481.8	1.618	745139.7	3669864	3.067	406.76	83	0	0
1520	3	5	745278.8	3669481.8	1.618	745138	3669868.5	3.067	411.57	84	0	0
1521	3	5	745278.8	3669481.8	1.618	745136.3	3669873.2	3.067	416.61	85	0	0
1522	3	5	745278.8	3669481.8	1.618	745134.6	3669877.8	3.067	421.41	86	0	0
1523	3	5	745278.8	3669481.8	1.618	745132.9	3669882.2	3.067	426.22	87	0	0
1524	3	5	745278.8	3669481.8	1.618	745131.3	3669887	3.067	431.24	88	0	0
1525	3	5	745278.8	3669481.8	1.618	745129.6	3669891.5	3.067	436.04	89	0	0
1526	3	5	745278.8	3669481.8	1.618	745127.9	3669896.2	3.067	441.08	90	0	0
1527	3	5	745278.8	3669481.8	1.618	745126.2	3669900.8	3.067	445.89	91	0	0
1528	3	5	745278.8	3669481.8	1.618	745124.6	3669905.2	3.067	450.7	92	0	0
1529	3	5	745278.8	3669481.8	1.618	745122.9	3669910	3.067	455.71	93	0	0
1530	3	5	745278.8	3669481.8	1.618	745121.2	3669914.5	3.067	460.52	94	0	0
1531	3	5	745278.8	3669481.8	1.618	745119.6	3669919.2	3.067	465.56	95	0	0
1532	3	5	745278.8	3669481.8	1.618	745117.9	3669923.8	3.067	470.37	96	0	0
1533	3	5	745278.8	3669481.8	1.618	745116.2	3669928.5	3.067	475.41	97	0	0
1534	3	5	745278.8	3669481.8	1.618	745114.5	3669933	3.067	480.21	98	0	0
1535	3	5	745278.8	3669481.8	1.618	745112.9	3669937.5	3.067	485	99	0	0

Record: 1501 of 5969

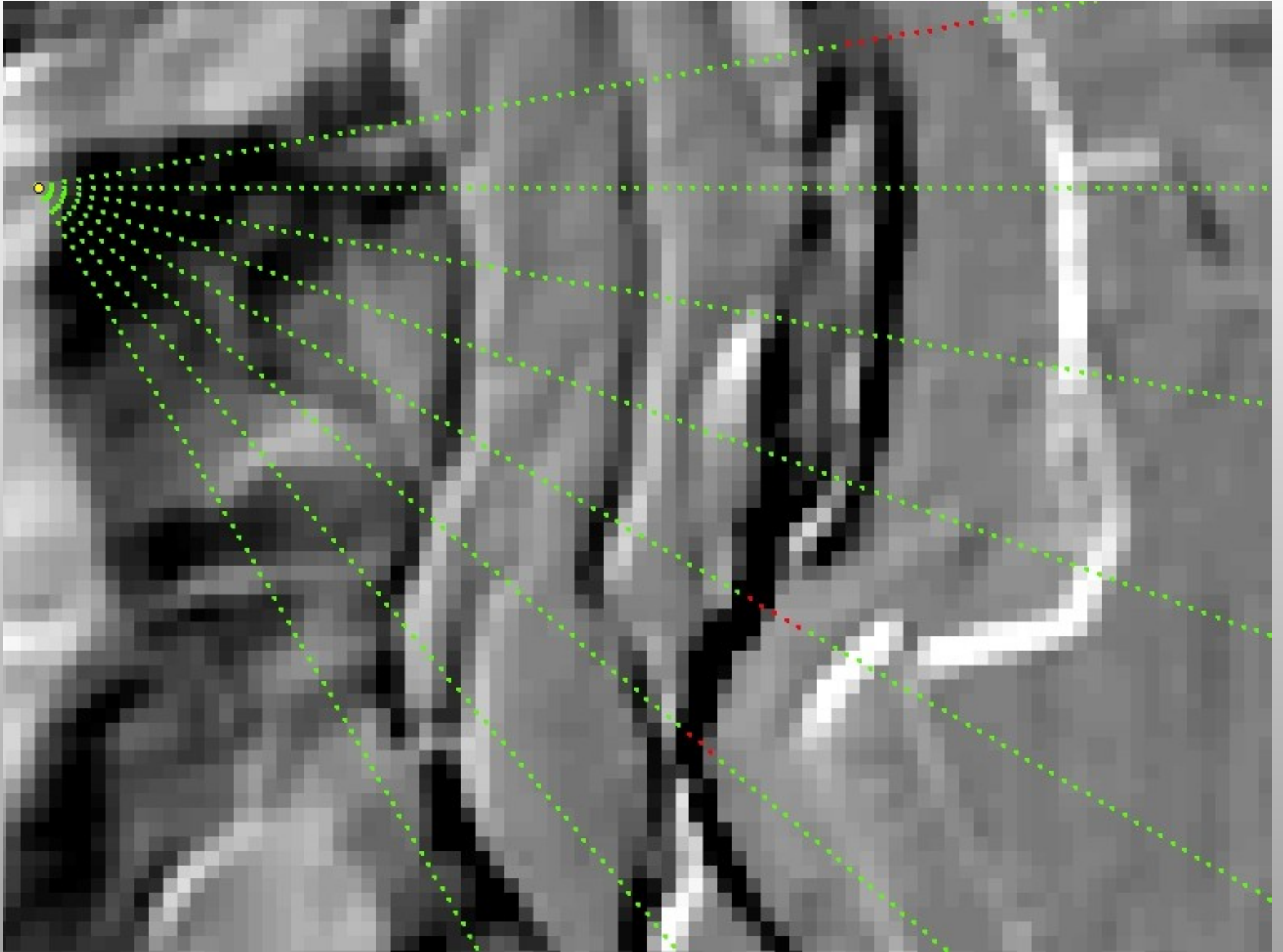
Datasheet View

FieldLOS of 1 = Visible to Observer, FieldLOS of 0 = Masked to

Yuma - 30,837 Observed Points



Yuma Site 1 (detail)



Overview of Methodology

- **Produce multi-vendor, geo-referenced viewsheds at defined observer locations that cover the extent of the collected field data and duplicate the observer and target heights used in the field.**

(Viewshed applications should be able to support floating point Z values when tested against TEC's photogrammetric DEMs.)

(No re-projection or re-sampling of DEMs is performed.)

- **Perform spatial queries on polygons derived from the raster viewsheds which determine the percentage agreement of the viewsheds' prediction relative with the field data.**

(Polygons must exactly fit the visible/masked delineations of the viewsheds from which they are derived.)

- **Compile statistics in spreadsheets and determine trends based on application results, terrain type, DEM source, DEM accuracy, resolution, precision, etc.**

Requirements/Rules of Thumb for Proper Analysis of Viewshed Overlays Against Field Data

- **Projection/datum must be properly defined for import of field and DEM data.**
- **When datums of field data and a DEM differ, transform observer and field coordinates to the datum of the DEM and run the viewshed in that datum. Avoid resampling of DEM data.**
- **Observer and target x,y,and z (height above ground) must be precisely defined.**
- **Earth curvature is to be applied if the application implements it.**
- **Viewsheds must be georeferenced output and not warped or otherwise resampled by evaluation software.**
(Assuming proper georeferencing of application viewsheds, the evaluation software's viewshed application does not gain an advantage)
- **For analysis in GIS, raster viewsheds must be converted to polygons to enable spatial queries. The resulting**

High Resolution Photogrammetric DEMs

<u>Test Area</u> <u>Value</u>	<u>DEM</u> <u>Resolution</u> (meters)	<u>Stated DEM</u> <u>Accuracy</u> (meters) <u>Hor.</u>	<u>Z-</u> <u>Vert.</u>
<u>Precision</u> (meters)			
Fort Benning 1.0 0.001		1	<1.0
Fort Hood 0.010	4	N/A	N/A
Irwin East 1.000	5	<1.0	1.0
Irwin West 0.100	5	0.03	0.04
Twentynine Palms 0.15 0.100		1	<1.0

Additional DEM Sources Tested by TEC Over Selected Areas

- **Light Detection and Ranging Data (LIDAR)*
(1 meter Resolution)**
- **Interferometric Synthetic Aperture Radar
(IFSARE)*
(3 Meter Resolution)**
- **DTED2
(1-Arc Second Posting Interval - ~30 Meter
Resolution)**
- **Shuttle Radar Topography Mission (SRT2)
(1-Arc Second Posting Interval - ~30 Meter
Resolution)**

Viewshed Applications Tested by TEC (to date) Against Line-of-Sight Field Data Using High Resolution Photogrammetric DEMs, LIDAR, IFSARE, DTED2, SRTM-DTED2, and DPPDB DEMs

- **ESRI ArcGIS 8.x Spatial Analyst/3D Analyst**
- **Intergraph GeoMedia Terrain 5.0**
- **Battlefield Terrain Reasoning and Awareness (BTRA-LOS) Viewshed**
- **MicroDEM/TerraBase II 7.0**
- **US Army Digital Topographic Support System (DTSS) 7.1.1**

Algorithms Run By US Army Training and Doctrine Command Analysis Center, White Sands Missile Range (TRAC-WSMR) Against LOS Field Data Using High Resolution DEMs*

- **Dynamic Tactical Simulation
(DYNTACS)**
- **Modular SemiAutomated Forces
(ModSAF)**
- **Bresenham**

▪ **Janus** * Details on these algorithms may be found in “The Effects of Different Line-of-Sight Algorithms and Terrain Elevation Representations on Combat Simulations”, Champion, Pankratz, and Fatale, 1995.

Example Yuma/Yakima Line-of-Sight Agreement

Yuma - 5 observers - 36,843 visible/masked points **with Field Data***

DTED2 - 80.3% of all field points identified correctly

SRT2 - 75.1% of all field points identified correctly

Yuma Disagreement Breakdown

DTED2 - 32.9% of visible field points and 67.1% of masked field points misidentified

SRT2 - 76.2% of visible field points and 23.8% of masked field points misidentified

→ **DTED2 over-predicts visibility**

→ **SRT2 under-predicts visibility**

Yakima - 5 observers - 34,109 visible/masked points

DTED2 - 84.0% of visible/masked field points identified correctly

SRT2 - 82.7% of all field points identified correctly

* Yakima Disagreement Breakdown